LIQUID CRYSTAL DISPLAY DEVICE AND A METHOD OF MANUFACTURING THE SAME FROM A FOLDED PLASTIC SHEET

BACKGROUND OF THE INVENTION

This invention relates to a liquid crystal display device having a flexible substrate and a method for manufacturing the device. More particularly, this invention relates to a liquid crystal display device having flexible electrode substrates between which a liquid crystal is disposed. The flexible electrode substrates are electrically connected to each other without the use of a conductor such as silver paste.

Liquid crystal display devices having glass substrates are well known. An electrode is spaced apart from a substrate by a liquid crystal. The electrode has a terminal and is electrically connected by a conductor to an electrode for the substrate on the terminal side. In this construction the reliability of the liquid crystal panel depends upon the reliability of the conductor. In practice, an electrically conductive adhesive is used as a conductor. However, this is not fully satisfactory since the adhesive often separates from the substrates. Additionally, the conventional devices are expensive to manufacture since a large amount of circuit printing and drying is required in order to form the conductors.

Accordingly, it is desirable to provide a liquid crystal display device which overcomes these problems.

SUMMARY OF THE INVENTION

Generally speaking, in accordance with the invention, a liquid crystal display device wherein the substrates are formed on a single sheet of flexible material with the electrode patterns formed on the sheet in a common plane and folded to provide an electrode terminal side and an opposed pattern side is provided. The substrate is then folded to provide a liquid crystal panel which does not require an interconnecting electrical connection between the two panels. Thus, the electrical connection of the invention is highly reliable, since the substrate is so folded as to define an inside diameter which is at least equal to the thickness of the device.

It is thus an object of the invention to provide an improved liquid crystal display device.

It is another object of the invention to provide an improved method for fabricating a liquid crystal display device using a single sheet of flexible material.

It is a principal object of the invention to eliminate the problem of conductor separation and to provide a liquid crystal display device which is highly reliable and which has an electrical connection between the electrode substrates.

Yet another object of the invention to provide a liquid crystal display device which is inexpensive to manufacture and which employs an assembly other than a conductor for use in making an electrical connection between the opposed liquid crystal electrode substrates, thereby eliminating the large amount of effort required for the formation of the conductor, including the steps of printing and drawing.

Still other objects and advantages of the invention will in part be obvious and will in part be apparent from the specification.

The invention accordingly comprises the features of construction, combination of elements and arrangement of parts which will be exemplified in the construction hereinafter set forth, and the steps and the relation of one or more of such steps with respect to each of the others, all as exemplified in the following detailed disclosure, and the scope of the invention will be indicated in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the invention, reference is had to the following description taken in connection with the accompanying drawings, in which:

FIG. **1** is a plan view of a substrate sheet in an unfolded condition for a liquid crystal display device in accordance with the invention;

FIG. **2** is a plan view of a liquid crystal display device of the invention;

FIG. **3** is a plan view of a substrate sheet in an unfolded condition for another embodiment of a liquid crystal device of the invention;

FIG. **4** is a plan view of a substrate sheet in an unfolded condition for a liquid crystal display device of a further embodiment of the invention;

FIG. **5** is a cross-sectional view of a liquid crystal display device made according to one embodiment of the invention;

FIGS. **6**(*a*), **6**(*b*) and **6**(*c*) are cross-sectional views of liquid crystal display devices made according to another embodiment of the invention;

FIGS. **7**(*a*), **7**(*b*), **7**(*c*) and **7**(*d*) are cross-sectional views of liquid crystal display devices made according to a further embodiment of the invention;

FIGS. **8**(*a*), **8**(*b*), **8**(*c*) and **8**(*d*) are cross-sectional views of liquid crystal display devices made according to still another embodiment of the invention;

FIG. **9** is a cross-sectional view of a display panel showing a step in the manufacturing process according to the invention;

FIGS. **10**(*a*) and **10**(*b*) are partial cross-sectional views of a liquid crystal display device made according to another embodiment of the invention;

FIGS. **11**(*a*)–**11**(*h*) each is a plan view of a substrate sheet in an unfolded condition for a liquid crystal display device according to an embodiment of the invention;

FIGS. **12**(*a*)–**25**(*a*) each is a plan view of a substrate sheet in an unfolded condition according to the invention;

FIGS. **12**(*b*)–**25**(*b*) each is a plan view of a liquid crystal display device made from the sheets of FIGS. **12**(*a*)–**25**(*a*), respectively according to the invention;

FIGS. **26**(*a*), **26**(*b*) and **26**(*c*) are cross-sectional views of two-layer liquid crystal display devices according to another embodiment of the invention; and

FIGS. **27**(*a*) and **27**(*b*) are cross-sectional views of threelayer liquid crystal display devices made according to a further embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The liquid crystal display device of the invention is formed from a flexible substrate sheet which is folded to form the opposed substrates of the display device. The substrate sheet is formed from a synthetic resin, such as a polyester, a cellulosic resin, phenoxy resin, polyethersulfone or a polysulfone or an acrylic resin. In addition, the substrate may be formed from a film or films of at least one of the resins. A polarizing film may also be attached to the substrate. In addition, the polarizing film may comprise a PVA film containing a dichroic dye